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Structural failures diagnosis in water networks Based on conditional probability theory

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Abstract* : Structural failures on the water pipeline network represent 53% of the causes of economic losses. To make the network profitable and minimize these losses, a diagnostic study is carried out based on the theory of conditional probabilities. A Bayesian probabilistic network is developed whose nodes represent the structural failures and their causes. In this study structural failures are considered as undesirable and dreaded events. From this study is easy to state that Bimetallic connections and degradation by aging of joints are the main causes of structural failures. An action plan is also determined from the inference in the developed Bayesian network. Actions are either: corrective actions, control and inspection actions, surveillance and monitoring. To show the effectiveness of the proposed tool, a case study on a water pipeline network is carried out. The actions taken in this paper's case study are: Remove or avoid metallic connections and Replace and repair joints, which represent mainly corrective actions. Other more complex probabilistic models will be developed in future work in order to take all failures on the water pipeline network.

Keys words : Water network; Failure diagnosis; Bayesian network

I. INTRODUCTION

The development of the urban fabric implies a complexity of the water network, the complexity of the tasks induced by technical and technological changes, as well as the multiplicity of stakeholders both internal and external to the management company of these networks make it necessary to draw up a Technical Guide for diagnosing failures in water networks. This guide will bring together all of the operator's know-how, which after being put in order, will constitute the technical reference system for water network management. It is designed to help unify the technical reference by establishing consistency between the different areas of activity (study, production, inspection, operation). In the past, maintenance manuals existed and maintenance benchmarks were used [1].

The maintenance activity of water networks is not new, but the operator wants to optimize maintenance activities and increase the availability of water networks while minimizing the economic impact and giving more rigor in the analysis of failure situations. Now, if the failures are known, the causes are multiple. Also, maintenance always hides surprises or the only way to avoid them is to automate the monitoring and diagnosis of water distribution systems [2], especially in the current context of smart cities.

Artificial intelligence methods have made a strong contribution in recent years to the treatment of problems related to the diagnosis of system failures in general and water networks in particular. Deep learning, ANN, Logistic regression, Support vector machine, and Decision tree are the main algorithms used in the literature [3]. Artificial Neural Networks (ANN) models are developed by [4]. Six ANN models are used for water failure prediction and for determine the benefit index. These intelligent ANN models allowed optimization of rehabilitation and maintenance activities and budget. In another contribution [5], logistic regression and support vector classification are chosen as intelligent predictive tools. Data are used from 4,393 pipe failures. Around 30% of failures could have been prevented by replacing only 3% of the network's pipes per year. The found results are very promising. The multi-label classification techniques are used to failures diagnosis in water pipeline network. Good contribution is presented by [6]. Discriminate analysis, logistic regression and random forest are used to predict failures for different periods. The proposed classification is show good prediction results.

Other researchers have used physical models or statistical approaches for the treatment of failures on water pipeline networks. Statistical survival analysis is used for decision making in water network maintenance [7, 8]. The main objective is to forecast failures and the rehabilitation of the network. Best decision making is to adopt short maintenance records instead of a long maintenance records. The use of statistical models [9] goes through a first step of clarification of model assumptions. The second one is the definition of the detailed data assumptions required for model calibration and finally the presentation of the probabilistic predictions available for each model. Also, probabilistic approaches are used in the literature, and one of theme is the Bayesian approach. A Bayesian model averaging is applied to identify the influential pipe-dependent and time-dependent covariates considering model uncertainties [10]. Also in this reference, Bayesian Weibull proportional hazard model is used to develop